



# National Institute of Standards & Technology

## Certificate

Standard Reference Material® 4404L

Thallium-201 Radioactivity Standard

Lot Number 37

Ampoule 1

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive thallium-201 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. A unit of SRM 4404L consists of approximately 5 mL of a solution, whose composition is specified in Tables 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

The certified **thallium-201** massic activity value, at a **Reference Time of 1500 EST, 24 June 2014**, is:  
 **$(9.072 \pm 0.116) \text{ MBq} \cdot \text{g}^{-1}$**

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a “measurement result” [2] obtained directly or indirectly from a “primary reference measurement procedure” [3]. The certified value is traceable to the derived SI unit, becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Table 1 and 2. Uncertainties for the certified quantities are expanded ( $k = 2$ ). The uncertainties are calculated according to the ISO and NIST Guide [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

**Expiration of Certification:** The certification of **SRM 4404L** is valid, within the measurement uncertainty specified, within its half-life-dependent useful lifetime, provided the SRM is handled in accordance with instructions given in this certificate (see “Instructions for Handling and Storage”). The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

**Maintenance of Certification:** NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser.

**Radiological and Chemical Hazard:** Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared in the Physical Measurement Laboratory, Radiation Physics Division, Radioactivity Group, M.P. Unterweger, Group Leader. The overall production, technical direction and physical measurement leading to certification were provided by R.K. Young and D.B. Golas, Guest Researchers from NRMAP, Incorporated.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Measurement Services Division.

Lisa R. Karam, Chief  
Radiation Physics Division

Gaithersburg, Maryland 20899  
August 2014

Robert L. Watters, Jr., Chief  
Measurement Services Division

Table 1. Certified Massic Activity of SRM 4404L, Lot 37, Ampoule 1

|   |                                 |
|---|---------------------------------|
| <b>Radionuclide</b>                                 | <b>Thallium-201</b>             |
| <b>Reference time</b>                               | <b>1500 EST, 24 June 2014</b>   |
| <b>Massic activity of the solution</b>              | <b>9.072 MBq•g<sup>-1</sup></b> |
| <b>Relative expanded uncertainty (<i>k</i> = 2)</b> | <b>1.28 %<sup>(a)</sup></b>     |

<sup>(a)</sup>The uncertainties on certified values are expanded uncertainties,  $U = ku_c$ . The quantity  $u_c$  is the combined standard uncertainty calculated according to the ISO and NIST Guides [4,5]. The combined standard uncertainty is multiplied by a coverage factor of  $k = 2$  and was chosen to obtain an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4404L, Lot 37, Ampoule 1

|  |   |
|--|---|
| Source description                             | Liquid in a flame-sealed 5-mL NIST borosilicate ampoule [1]   |
| Solution composition                           | 1.0 mol•L <sup>-1</sup> HNO <sub>3</sub> with 54 µg Tl <sup>+</sup> per gram of solution (as TlNO <sub>3</sub> )  |
| Solution density                               | (1.030 ± 0.002) g•mL <sup>-1</sup> at 20.0 °C <sup>(a)</sup>  |
| Solution mass                                  | (5.1550 ± 0.0003) g <sup>(a)</sup>  |
| Photon-emitting impurities (at reference time) | <sup>200</sup> Tl: (10 ± 3) kBq•g <sup>-1</sup> (a,b)<br><sup>202</sup> Tl: (26 ± 5) kBq•g <sup>-1</sup>  |
| Half lives used                                | <sup>201</sup> Tl: (3.0421 ± 0.0017) d <sup>(c)</sup><br><sup>200</sup> Tl: (26.1 ± 0.1) h <sup>(d)</sup><br><sup>202</sup> Tl: (12.31 ± 0.08) d <sup>(e)</sup>   |
| Calibration method (and instruments)           | Measurements of ionization current ratios relative to radium-226 reference sources using NIST pressurized "4π"γ ionization chamber "B" calibrated using a thallium-201 solution whose activity was determined by the 4π(e+X)-γ live-timed anticoincidence efficiency-extrapolation technique. |

<sup>(a)</sup>The stated uncertainty is two times the standard uncertainty.

<sup>(b)</sup>The estimated lower limits of detection for photon-emitting impurities, expressed as massic photon emission rates, as of 24 June 2014 were:

$2 \times 10^3 \text{ s}^{-1}\cdot\text{g}^{-1}$  for energies between 30 keV and 55 keV,  
 $9 \times 10^3 \text{ s}^{-1}\cdot\text{g}^{-1}$  for energies between 60 keV and 90 keV,  
 $3 \times 10^3 \text{ s}^{-1}\cdot\text{g}^{-1}$  for energies between 95 keV and 180 keV,  
 $7 \times 10^2 \text{ s}^{-1}\cdot\text{g}^{-1}$  for energies between 185 keV and 420 keV,  
 $1 \times 10^3 \text{ s}^{-1}\cdot\text{g}^{-1}$  for energies between 430 keV and 450 keV,  
 $7 \times 10^2 \text{ s}^{-1}\cdot\text{g}^{-1}$  for energies between 460 keV and 1260 keV,  
 $6 \times 10^2 \text{ s}^{-1}\cdot\text{g}^{-1}$  for energies between 1270 keV and 1440 keV,  
 $8 \times 10^2 \text{ s}^{-1}\cdot\text{g}^{-1}$  for energies between 1450 keV and 1470 keV, and  
 $5 \times 10^2 \text{ s}^{-1}\cdot\text{g}^{-1}$  for energies between 1480 keV and 2000 keV,

provided that any impurity photons are separated by four keV or more from photons emitted in the decay of thallium-201.

<sup>(c)</sup>The stated uncertainty is the standard uncertainty. See reference 6.

<sup>(d)</sup>The stated uncertainty is the standard uncertainty. See reference 7.

<sup>(e)</sup>The stated uncertainty is the standard uncertainty. See reference 8.

Table 3. Uncertainty Evaluation for the Massic Activity of SRM 4404L, Lot 37

|   | Uncertainty component   | Assessment Type <sup>(a)</sup> | Relative standard uncertainty contribution on massic activity of thallium-201 (%) |
|---|---|--------------------------------|---|
| 1   | Ionization-chamber measurement precision on this solution; standard deviation of the mean for five sets of measurements on ten ampoules | A                              | 0.05  |
| 2   | "4 $\pi$ " $\gamma$ ionization-chamber calibration factor   | B                              | 0.58  |
| 3   | Correction for photon-emitting impurities in this solution  | B                              | 0.1   |
| 4   | Decay correction for radium-226 reference source to correct the calibration factor (for half-life uncertainty of 0.44 %)                | B                              | 0.0006  |
| 5   | Radium reference source positioning   | B                              | 0.05  |
| 6   | Electrometer response linearity   | B                              | 0.1   |
| 7   | Gravimetric mass measurements   | B                              | 0.05  |
| 8   | Decay correction for thallium-201 (for half-life uncertainty of 0.056 %)  | B                              | 0.0006  |
| 9   | Detection limits for photon-emitting impurities   | B                              | 0.2   |
| <b>Relative combined standard uncertainty</b>             |   |                                | <b>0.64</b>   |
| <b>Relative expanded uncertainty (<math>k = 2</math>)</b> |   |                                | <b>1.28</b>   |

<sup>(a)</sup>Type A denotes evaluation by statistical methods; B denotes evaluation by other methods.

## INSTRUCTIONS FOR HANDLING AND STORAGE

**Handling:** If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of both the radioactivity and the strong acid. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure. Refer to the SDS for further information.

**Storage:** SRM 4404L should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

## REFERENCES

- [1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*; available at <http://www.nist.gov/pml/div682/grp04/srm.cfm>.
- [2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sèvres Cedex, France; p. 19 (2012); available at [http://www.bipm.org/utls/common/documents/jcgm/JCGM\\_200\\_2012.pdf](http://www.bipm.org/utls/common/documents/jcgm/JCGM_200_2012.pdf).
- [3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sèvres Cedex, France; p. 18 (2012); available at [http://www.bipm.org/utls/common/documents/jcgm/JCGM\\_200\\_2012.pdf](http://www.bipm.org/utls/common/documents/jcgm/JCGM_200_2012.pdf).
- [4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement*; (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology: BIPM, Sèvres Cedex, France (2008); available at [http://www.bipm.org/utls/common/documents/jcgm/JCGM\\_100\\_2008\\_E.pdf](http://www.bipm.org/utls/common/documents/jcgm/JCGM_100_2008_E.pdf).
- [5] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at <http://physics.nist.gov/Pubs/>.
- [6] Laboratoire National Henri Becquerel; *Table of Radionuclides, Recommended Data* (updated 15 June 2005); available at [http://www.nucleide.org/DDEP\\_WG/DDEPdata.htm](http://www.nucleide.org/DDEP_WG/DDEPdata.htm) (accessed June 2014).
- [7] The Evaluated Nuclear Structure Data File (ENSDF), National Nuclear Data Center, Brookhaven National Laboratory, Upton, New York, full evaluation 2006, Nuclear Data Sheets 108, 1471 (2007); available at <http://www.nndc.bnl.gov/ensdf/index.jsp> (accessed June 2014).
- [8] The Evaluated Nuclear Structure Data File (ENSDF), National Nuclear Data Center, Brookhaven National Laboratory, Upton, New York, full evaluation 2007, Nuclear Data Sheets 109, 699 (2008); available at <http://www.nndc.bnl.gov/ensdf/index.jsp> (accessed June 2014).

*Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail [srminfo@nist.gov](mailto:srminfo@nist.gov); or via the internet at <http://www.nist.gov/srm>.*